TOP PHYSICS AT DØ

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RunII at the Fermilab Tevatron officially began March 1, 2001. The upgraded accelerator provides p-pbar collisions at a centre of mass energy of 1.96TeV with luminosities which will allow the collection of approximately 20 times the RunI dataset in the period known as RunIIa (2fb^{-1}). The DØ detector has undergone significant upgrades as well, including a new tracking system (with a silicon tracker and solenoidal magnetic field), a redesigned trigger system and new readout electronics. These improvements lead to an increased top cross-section, improved b-tagging and higher delivered luminosity and will give a sample of a few thousand top quark events during RunIIa. This greatly increased sample of top events will allow study of top quark properties to a level which was not possible in the statistically limited RunI dataset. This includes the search for electroweak top production, the study of the decay properties of the top (including W helicity), refinement of the top mass measurement and measurement of the ttbar cross-section. Prospects for these measurements will be presented along with the current status of these studies.

1 Introduction

The top quark was discovered jointly by the DØ and CDF collaborations in 1995. Subsequently many measurements of top quark properties have been made based on RunI data (1992-1996) [1]. A significant upgrade of both the accelerator complex and the two experiments is now complete and data-taking has begun in the period known as RunII.

The next section discusses top quark production and decay at the Fermilab Tevatron. A review of measurements made based on Run I data is then presented. This is followed by a description of the upgrade for RunII and the projected improvements to top quark measurements. Finally, the current status of the DØ experiment is highlighted.

2 Top Quark Production and Decay at the Tevatron

A representative set of Feynman diagrams responsible for top quark production at the Fermilab Tevatron are show in Figure 1. Top quarks are dominantly produced in pairs via the strong interaction ($t\bar{t}$ production) but can also be produced singly via the weak interaction.

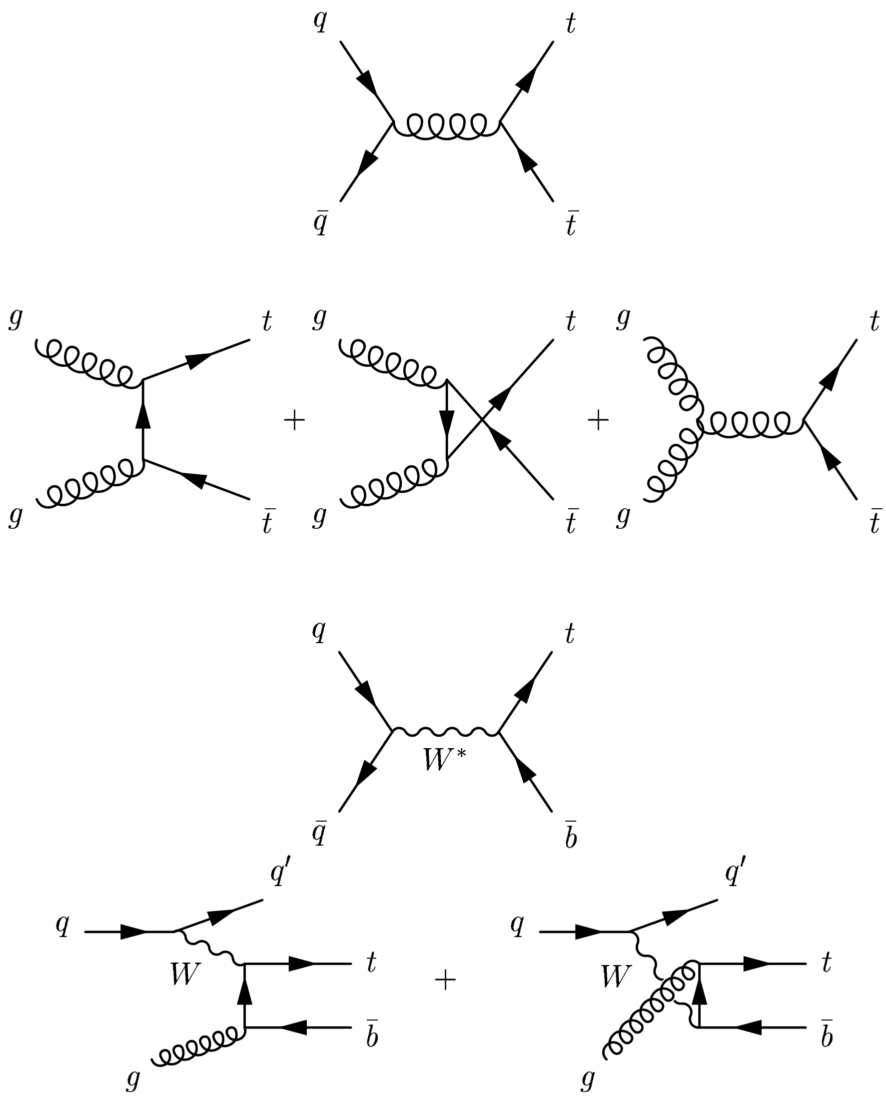

Figure 1. Representative Feynman diagrams for top quark production at the Tevatron.

Since the lifetime of the top ($\tau \approx 5 \times 10^{-25}$s) is shorter than the time required to hadronize, top jets do not form. In the Standard Model the top

Table 1. Branching ratios for top decay (top pair production)

all jets	44%
l+jets (l=e,μ)	30%
τ+X	21%
dilepton(ee,eμ,$\mu\mu$)	5%

quark decays to a W boson and a b quark with a branching ratio of $\approx$1. This allows the spin properties of the top to be transmitted to its decay products and measured. This makes the production of the top quark the first opportunity to study the spin of a "bare" quark.

Top events are typically classified by the decay products of the W produced in the top decay. Lepton + jets events involve the decay of one W to jets and the other to leptons, dilepton events involve both Ws decaying leptonically and all jets involve both Ws decay hadronically. The predicted branching ratios for each of these classifications is shown in Table 1.

3 Measurement of Top Quark Properties in RunI

Several properties of the top quark have been measured since its discovery was announced in 1995. Among these are the top mass, production cross-section, $t\bar{t}$ spin correlation, W helicity from top decays and limits on electroweak top production cross-sections. A brief review of some of these results is presented herein.

3.1 Mass

The mass of the top quark is an important parameter in the Standard Model. When combined with LEP electroweak precision measurements it puts much more stringent constraints on the value of the Higgs mass than precision electroweak measurements alone.

The DØ measurement of the top quark mass from RunI data is $172.1 \pm 5.2 \pm 4.9$ GeV [2]. Combining with the CDF measurement yields 174.3 ± 5.1 GeV [3].

3.2 $t\bar{t}$ Cross-Section

For top pair production at 1.8 TeV centre-of-mass energy DØ measures a cross-section of $5.69 \pm 1.21 \pm 1.04$ pb using 80 candidate events from all top decay channels.

3.3 $\mathrm{t\bar{t}}$ *Spin Correlation*

Top quarks produced via the strong interaction (as in $\mathrm{t\bar{t}}$ production) are expected to be unpolarized. However, event by event the spins of the two tops in the event are correlated. This is the first opportunity to study a quark almost free of confinement effects. It can also yield a lower limit on the CKM matrix element $|\mathrm{V_{tb}}|^2$ without assuming three generations of quark families.

DØ measured a correlation coefficient κ to be greater than -0.25 at the 68% confidence level [5]. This is in agreement with the Standard Model prediction of $\kappa = 0.88$.

3.4 *W Helicity in Top Decays*

As mentioned previously, the top quark decays to a W and a b quark nearly 100% of the time. The produced W will be polarized with the fraction of longitudinal Ws described by

$$B(t \to W_0 b) = \frac{m_t^2}{m_t^2 + 2M_w^2} \tag{1}$$

which yields a longitudinal fraction of approximately 70%. In the limit that the b-mass goes to zero the remainder of the produced Ws are in the left-handed spin state and the right-handed spin state is disallowed. The DØ measurement of the W helicity from top decays in RunI data is ongoing.

3.5 *Electroweak Top Production*

At a hadron collider the top quark can also be produced singly via the weak interaction (see Figure 1). The cross-section for electroweak top quark production is directly proportional to the square of the CKM matrix element $\mathrm{V_{tb}}$. The measurement of this cross-section combined with the top branching ratio measurement from the $\mathrm{t\bar{t}}$ channel can provide the first direct measurement of $\mathrm{V_{tb}}$. Electroweak top quark production also provides a source of highly polarized top quarks. This is the first opportunity to measure the polarization of a bare quark.

DØ placed upper limits on the cross-sections of both s-channel and t-channel electroweak top production. These limits are 17 pb and 22 pb respectively [6]. These should be compared to theoretical predictions of 0.75 pb and 1.47 pb at 1.8 TeV centre-of-mass energy.

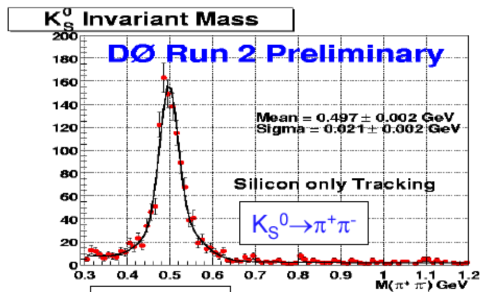

Figure 2. K_s^0 mass distribution from silicon-only tracking

4 The Upgrade

4.1 Tevatron

Since the end of RunI data-taking in 1996 the Fermilab Tevatron has undergone a major upgrade. The available centre-of-mass energy has increased from 1.8 TeV to 1.96 TeV while the peak instantaneous luminosity will increase from approximately $1 \times 10^{31} cm^{-2} s^{-1}$ to 5×10^{32} during the RunII data-taking period. This will allow the collection of 2 fb^{-1} in the period known as RunIIa and 15 fb^{-1} for the whole of RunII.

4.2 DØ

The DØ detector has been significantly upgraded for RunII. The tracking system has been completely replaced. It now includes a 2 T solenoidal field, a silicon microstrip tracker with more than 800000 channels of readout, a fibre tracker and central and forward preshower detectors. These new detectors are fully installed and commissioned. Figure 2 shows reconstructed K_s^0 mass using the silicon microstrip tracker. In addition to the tracking upgrade DØ has new readout electronics in every system, a new trigger/DAQ system and completely rewritten software for RunII.

5 Top Physics in RunII

The improvements to the Tevatron and the DØ detector for RunII will benefit measurement of top quark properties in several ways. First, the greatly increased signal samples provided by the upgraded Tevatron will reduce statistical errors on existing measurements. Greater signal samples will also make

Table 2. Projected precision for top quark measurements in RunIIa

Measurement	RunI	RunIIa
Mass	± 7 GeV	± 2-3 GeV
$\sigma(t\bar{t})$	$\pm 27\%$	$\pm 8\%$
$t\bar{t}$ spin	$\kappa > -0.25$	2σ
EW top	< 17, 22pb	$\delta V_{tb} \simeq$ 10-15%

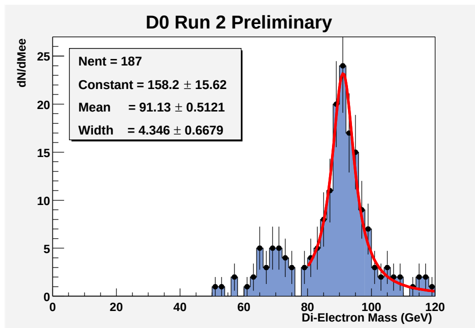

Figure 3. Z mass distribution from Z$\rightarrow$ee events

possible analyses which could not be done in RunI. This increase in integrated luminosity also benefits the understanding of background processes as larger calibration samples of Z and W will be produced. The second benefit comes from the improved DØ tracking system. The ability to tag b-jets using displaced vertices and the use of tracking to calibrate the jet energy scale of the calorimeter will both contribute to improved measurement of top quark properties. Some projected improvements for RunIIa (2 fb^{-1}) are shown in Table 2.

6 Status

DØ is fully instrumented and has been taking data since April 2001. The Tevatron luminosity has been increasing slowly since the beginning of the run but is still well below design. DØ has used the data taken to this point to commission and understand the new detector. An example illustrating the quality of the calibration of the calorimeter is shown in the Z mass peak reconstructed from electrons shown in Figure 3.

7 Summary

RunII at the Tevatron has begun. Though it is still too early to report new results in measurements of top quark properties much progress has been made in understanding the new DØ detector. RunIIa will deliver 15-20 times more integrated luminosity than was available in RunI datasets. This, combined with an upgraded detector performance, will lead to a significant improvement in our understanding of the top quark in RunII.

References

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